Original Article

Prehospital and in-hospital quick Sequential Organ Failure Assessment (qSOFA) scores to predict in-hospital mortality among trauma patients: an analysis of nationwide registry data

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Aim: The quick Sequential Organ Failure Assessment (qSOFA) score can be used to predict in-hospital mortality in trauma patients. We sought to determine whether repeatedly calculating the qSOFA score improves its discriminative ability in predicting in-hospital mortality in trauma patients.

Methods: We undertook a multicenter retrospective study, analyzing 90,974 trauma patients registered in the Japan Trauma Data Bank (a nationwide trauma registry) from 2004 to 2017. Patients included were ≥18 years old and transferred directly to hospitals from their respective scenes of injury. We calculated the qSOFA score at two time points: at the scene (prehospital qSOFA score) and on arrival at the hospital (hospital qSOFA score). We evaluated the discriminative ability of repeated calculations of the qSOFA score. The primary outcome in consideration was in-hospital mortality.

Results: In-hospital mortality occurred in 5604 patients (6.2%). The predictive accuracy of the hospital qSOFA score was higher than that of the prehospital qSOFA (area under the receiver operating characteristics curve [AUROC] 0.74 vs. 0.69, $P < 0.0001$) in predicting in-hospital mortality. However, the mean qSOFA score had the highest predictive accuracy (AUROC 0.76, $P < 0.0001$). If the hospital qSOFA score was increased compared to the prehospital score, this indicated an approximately 2-fold to 4-fold increase in in-hospital mortality.

Conclusions: Repeated calculations of qSOFA score improved its ability to predict in-hospital mortality in trauma patients. Specifically, we should consider an increasing qSOFA score as a "red flag" to clinicians in the emergency department.

Key words: in-hospital mortality, quick sequential organ failure assessment score, trauma

INTRODUCTION

SEVERE TRAUMA IS time-sensitive and requires timely intervention both during prehospital and in-hospital care as illustrated in the "golden hour concept".[1] Most trauma fatalities occur during the first several hours after the injury,[2] and even initially stable patients can deteriorate rapidly. Therefore, repeated evaluation is needed to predict and recognize such deterioration and, accordingly, initiate aggressive care (e.g. activate designated trauma team).

In addition to the Sequential Organ Failure Assessment (SOFA) score, the quick SOFA (qSOFA) score was recently developed to identify severe infections and initiate timely interventions.[3,4] The qSOFA score is easy to calculate and is therefore useable at the point of care. The qSOFA score was also found to be strongly associated with in-hospital mortality in trauma patients in prehospital and emergency department settings.[5-7] When compared to a single calculation, repeated calculation of the qSOFA score seems to improve the predictive accuracy for in-hospital mortality in patients with infection.[8] This could hold true even for patients with trauma, that is, we might be able to predict in-hospital mortality more accurately using repeated calculations of the qSOFA score; however, there is still no evidence to prove this hypothesis.

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We therefore undertook this study on patients registered in the Japan Trauma Data Bank (JTDB), a nationwide trauma registry. Its aim was to evaluate the predictive accuracy of repeated calculations of the qSOFA score in identifying patients at high risk of death who may require emergency intervention.

METHODS

THIS IS A multicenter retrospective observational study using patients registered with the nationwide trauma registry, JTDB, during the years 2004 to 2017. The JTDB was established in 2003 and had 264 Japanese institutes as participants as of 2017. All trauma patients with an abbreviated injury scale (AIS) of ≥3 admitted in these institutes were registered in JTDB. The AIS data was recorded using AIS 90 Update 98.[9] We then retrieved and analyzed the anonymized dataset from JTDB. This study was approved by the institutional review board at Wakayama Medical University (approval number 2632), which waived the requirement of informed consent due to the retrospective design of this study. This trial was registered in the University Hospital Medical Information Network-Clinical Trials Registry (UMIN-CTR), UMIN000037249 (registered 3 July 2019, https://upload.umin.ac.jp/cgi-open-bin/ctr/ctr_view.cgi?recptno=R000042402).

We included trauma patients aged 18 years or older who were transported directly to the participating hospitals from the scene of injury. We excluded patients who were transferred from other hospitals, who were not evaluated or transported by emergency medical services, those with prehospital cardiopulmonary arrest, and those with burn injuries. We regarded patients with prehospital severe hypotension (systolic blood pressure <50 mmHg) or bradycardia (heart rate <30 b.p.m.) as cases of cardiopulmonary arrest. We also excluded patients with missing data regarding important variables (age, sex, outcomes at discharge, transportation time, and vital signs). We considered extremely long transportation times (>60 min) as missing values because these values were unrealistic in Japanese prehospital settings and/or lacked external validity.

The qSOFA score is calculated based on three variables: consciousness (not alert), respiratory rate (≥22 breaths/min), and systolic blood pressure (≤100 mmHg). If each variable met the criterion, one point was given; otherwise, zero points were given. The qSOFA score ranges from 0 to 3, with higher scores indicating greater severity.[3] In this study, the qSOFA score was calculated twice: the prehospital qSOFA was calculated using the first vital signs measured during prehospital medical examinations and the hospital qSOFA score was calculated using the first vital signs measured on arrival at the hospitals. We also calculated the mean qSOFA score between the prehospital and hospital qSOFA scores. To assess patient consciousness, the qSOFA score was calculated from the Japan Coma Scale (JCS) during the prehospital period and the Glasgow Coma Scale (GCS) in-hospital. A JCS score of 0 indicated alertness, and scores of 1-20, 30-200, and 300 indicated responsiveness to voice, responsiveness to pain, and unresponsiveness, respectively.[10] “Not alert” was defined as a JCS higher than 0 or GCS lower than 15.

According to a recent study, we classified patients into six trajectory groups based on prehospital and hospital qSOFA scores to validate this classification:[8] (i) prehospital qSOFA score = 0 (very low) and hospital qSOFA score < 2 (remained low), (ii) prehospital qSOFA score = 0 (very low) and hospital qSOFA score ≥ 2 (became high), (iii) prehospital qSOFA score = 1 (low) and hospital qSOFA score < 2 (remained low), (iv) prehospital qSOFA score = 1 (low) and hospital qSOFA score ≥ 2 (became high), (v) prehospital qSOFA score = 2 or 3 (high) and hospital qSOFA score < 2 (became low), (vi) prehospital qSOFA score = 2 or 3 (high) and hospital qSOFA score ≥ 2 (remained high).

The primary outcome of this study was in-hospital mortality. The secondary outcome was the requirement of transfusion within 24 h of admission.

Statistical analysis

We expressed continuous variables as means ± standard deviations or medians and interquartile ranges. We expressed categorical variables as numbers and percentages (%). We compared survivors and non-survivors using the χ^2-test for categorical variables and the *t*-test or Wilcoxon’s rank-sum test for continuous variables. We used the area under the receiver operating characteristics (AUROC) curve to determine the predictive ability of the qSOFA score for in-hospital mortality and requirement of transfusion within 24 h of admission. Multiple comparisons of the AUROC for in-hospital mortality and requirement of transfusion within 24 h of admission were made using a multiple comparison test (Bonferroni method). We also calculated the sensitivity and specificity of each qSOFA score using a cut-off score ≥2, which was the standard cut-off point proposed in the Sepsis-3 definition.[3] We evaluated the association between the six trajectory groups and outcomes using two logistic regression models. In the multivariate logistic regression models, we used two sets of adjusters as age and sex in the “partial adjustment model” and age, sex, mechanism of injury, cause of injury, and injury severity score in the “full adjustment model”. There was no missing data in the partial adjustment model and we removed all patients with missing data from the full adjustment model. For all analysis, a two-sided *P*-value of <0.05 was considered statistically significant. All analyses were undertaken using JMP Pro software version 12.2 (SAS Institute, Cary, NC, USA).

RESULTS

THIS STUDY INCLUDED 90974 adult trauma patients registered in JTDB (Fig. 1). We present the patient characteristics in Table 1. The mean age was 58.4 years and the population showed male gender predominance (63.6%). The transportation time was 12 min and was similar for both survivors and non-survivors. Both prehospital and hospital qSOFA evaluations had a median score of 1.

In-hospital mortality occurred in 5604 (6.2%) patients; 11,341 (12.5%) patients required transfusion within 24 h of admission. We present a graph of the receiver operating characteristic curve for each qSOFA score against in-hospital mortality and requirement of transfusion within 24 h of admission in Figures 2 and 3, respectively. We found that the AUROC curves differed significantly between all three pairs of qSOFA scores (prehospital qSOFA < hospital qSOFA < mean qSOFA). Using the cut-off as ≥2 for each qSOFA score, we found that the specificity increased from prehospital, to hospital, to mean qSOFA score, while the sensitivity decreased (Table 2).

We present the crude in-hospital mortality rate for each trajectory group in Figure 4. Overall, if the hospital qSOFA score was increased compared to the prehospital score, this indicated a 2-fold to 4-fold increase in in-hospital mortality. In logistic regression models, an increasing score was significantly associated with increased hospital mortality and requirement of transfusion even after adjustment for patient characteristics and anatomical severity of trauma (Tables 3 and 4).

DISCUSSION

IN THIS STUDY, we found that repeated calculations of the qSOFA score improved the AUROC curve for in-hospital mortality in trauma patients (prehospital < hospital < mean). We found a similar predictive ability when considering the requirement of transfusion within 24 h of admission. Among those patients with a prehospital qSOFA score of 0, very few (1 in 20) increased to 2 points or higher in the hospital qSOFA, which indicates a 4-fold increase in crude in-hospital mortality rate. Among those patients with a prehospital qSOFA score of 1, some (1 in 6) increased to 2 points or higher in the hospital qSOFA, which indicates a 2-fold increase in crude in-hospital mortality rate.

Previous studies of trauma patients reported that the AUROC curve of the qSOFA score calculated in the emergency department (0.73) was higher than that of the qSOFA score calculated in prehospital settings (0.70) when predicting in-hospital mortality.[5,7] In the present study, we obtained concordant results, that is, the AUROC curve of the hospital

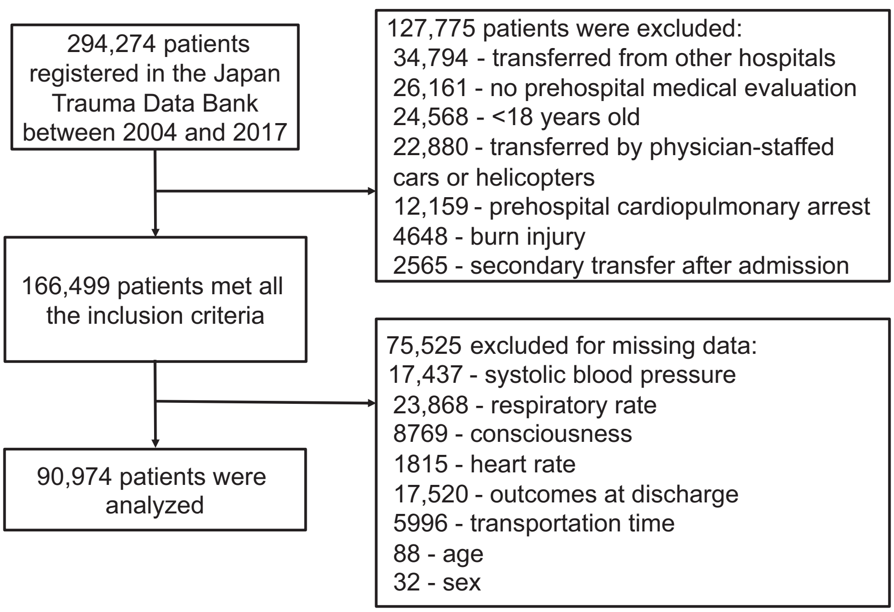

Fig. 1. Flowchart of the selection process of 90,974 trauma patients registered in the Japan Trauma Data Bank, 2004–2017.

Table 1. Characteristics of 90,974 trauma patients registered in the Japan Trauma Data Bank, 2004–2017

Characteristic	All patients (n = 90974)	Survivors (n = 85370)	Non-survivors (n = 5604)	P-value
Age, years; mean ± SD	58.4 ± 21.7	57.7 ± 21.7	68.7 ± 18.2	<0.0001
Male sex	57,897 (64)	54,193 (64)	3704 (67)	<0.0001
Mechanism of injury†				
Blunt trauma	86,311 (96)	80,943 (96)	5368 (99)	<0.0001
Penetrating trauma	3421 (4)	3342 (4)	79 (2)	
Cause of injury‡				
Accident	76,416 (86)	71,730 (86)	4686 (89)	<0.0001
Suicide	5035 (6)	4731 (6)	304 (6)	
Assault	1529 (2)	1474 (2)	55 (1)	
Workplace injuries	5245 (6)	5067 (6)	178 (3)	
Others	809 (1)	766 (1)	43 (1)	
Prehospital care				
Oxygen supplementation	47,660 (52)	43,472 (51)	4188 (75)	<0.0001
Intravenous infusion	530 (1)	469 (1)	61 (1)	<0.0001
Transportation time, min; median (IQR)	12 (7–18)	12 (7–18)	12 (8–17)	0.25
Injury severity score, median (IQR)§	10 (9–19)	10 (9–17)	25 (18–34)	<0.0001
Consciousness not alert				
At prehospital	48,693 (54)	43,668 (51)	5025 (90)	<0.0001
At hospital	36,781 (40)	31,857 (37)	4924 (88)	<0.0001
Respiratory rate ≥22 breaths/min				
At prehospital	37,808 (42)	34,851 (41)	2957 (53)	<0.0001
At hospital	34,568 (38)	31,826 (37)	2742 (49)	<0.0001
Systolic blood pressure ≤100 mmHg				
At prehospital	11,381 (13)	10,320 (12)	1061 (19)	<0.0001
At hospital	8860 (10)	7675 (9)	1185 (21)	<0.0001
qSOFA score				
At prehospital, median (IQR)	1 (0–2)	1 (0–2)	2 (1–2)	<0.0001
At hospital, median (IQR)	1 (0–1)	1 (0–1)	2 (1–2)	<0.0001
Mean, median (IQR)	1 (0.5–1.5)	1 (0.5–1.5)	1.5 (1–2)	<0.0001

IQR, Interquartile range; qSOFA, quick Sequential Organ Failure Assessment; SD, standard deviation.
Data are shown as n (%) unless otherwise indicated.
†Mechanism of injury was missing for 1242 patients.
‡Cause of injury was missing for 1940 patients.
§Injury severity score was missing for 1610 patients.

qSOFA score (0.74) was higher than that of the prehospital qSOFA score (0.69) when predicting in-hospital mortality.

Other studies on patients with suspected infections reported that repeated calculations of the qSOFA score improved the predictive accuracy for in-hospital mortality.[8] Similarly, our study showed that the AUROC curve of the mean qSOFA score was higher than that of the prehospital or hospital qSOFA. Clinically, a single calculation of the qSOFA score seems to have the limitation of a relatively low specificity. Furthermore, a recent study showed that the discrimination of prehospital trauma models other than the qSOFA score is inadequate for predicting in-hospital mortality, which indicates the limitation of single calculation, irrespective of models.[11] Repeated calculations of the qSOFA score have a higher specificity for identifying patients at high risk of death.

As our study showed, we can predict in-hospital mortality in trauma patients more precisely by repeatedly assessing the qSOFA score. We agree that it is not surprising that the repeated calculations of any score improve discrimination. However, the interpretation of the repeated calculations of the qSOFA score might be too complex in busy clinical settings. So, we proposed simple interpretations of six trajectory groups that were developed in a recent study.[8] Specifically, an increasing qSOFA score should be regarded as a "red flag" by

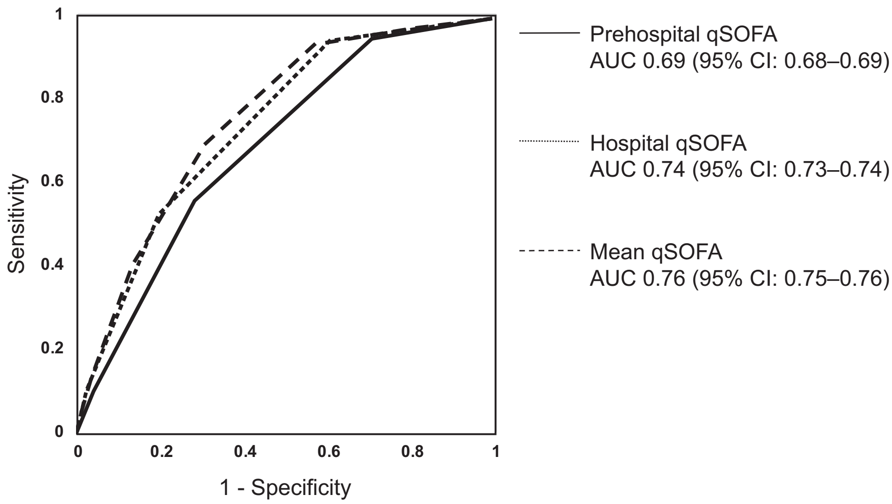

Fig. 2. Analysis of the areas under the receiver operating characteristic curves (AUC) for the quick Sequential Organ Failure Assessment (qSOFA) score for in-hospital mortality of Japanese trauma patients. CI, confidence interval.

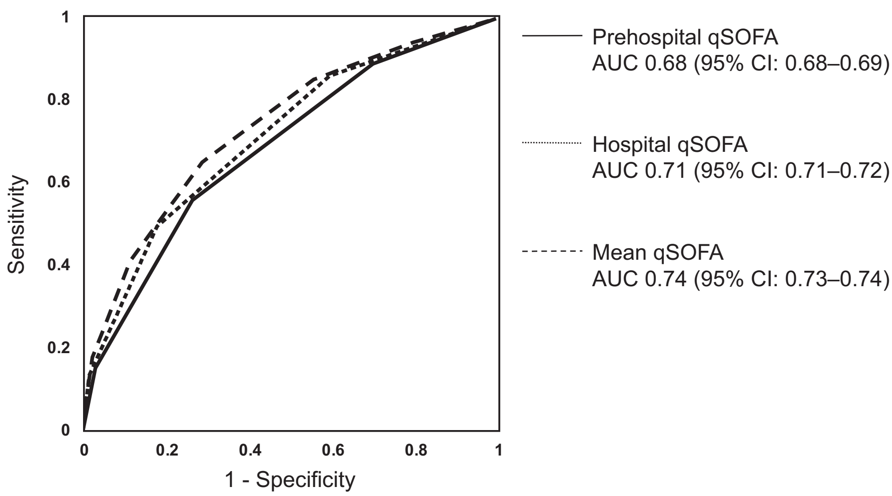

Fig. 3. Analysis of the areas under the receiver operating characteristic curves (AUC) for the quick Sequential Organ Failure Assessment (qSOFA) score for the requirement of transfusion within 24 h of admission of Japanese trauma patients. CI, confidence interval.

clinicians who should then further evaluate patients and implement more intensive interventions, such as activating a designated trauma team and massive transfusion, even if the patients are initially stable. In using the qSOFA score, good clinical judgement is vital, because the discrimination ability of the qSOFA is not enough to "rule in" or "rule out" severe patients. We can easily carry out serial point-of-care evaluations of the qSOFA score without any special equipment, which enhances the usefulness of the qSOFA score.

Our study has several limitations. First, our study population exclusively included Japanese patients. Consequently, we cannot extrapolate these results to other circumstances. In fact, a previous study showed that the demographic characteristics of patients with trauma in Japan were different from those in other developed countries.[12] In particular, the prehospital treatment provided by emergency medical services might differ from area to area. In our study cohort, approximately half of the patients received non-invasive oxygen supplementation and few patients received i.v.

Table 2. Sensitivity and specificity of each quick Sequential Organ Failure Assessment (qSOFA) score in Japanese trauma patients using a threshold of ≥2

	Sensitivity	Specificity
In-hospital mortality		
Prehospital qSOFA	56.1 (54.8–57.4)	71.5 (71.1–71.8)
Hospital qSOFA	52.8 (51.5–54.1)	80.1 (79.8–80.4)
Mean qSOFA	40.6 (39.3–41.9)	86.5 (86.2–86.7)
Requirement of transfusion within 24 h of admission		
Prehospital qSOFA	55.9 (55.0–56.8)	73.4 (73.1–73.7)
Hospital qSOFA	49.6 (48.6–50.5)	82.0 (81.7–82.3)
Mean qSOFA	41.2 (40.3–42.1)	88.5 (88.3–88.7)

Data are shown with 95% confidence intervals.

infusion of fluids. Furthermore, Japanese emergency medical services are not allowed to perform tracheal intubation for patients except in case of cardiopulmonary arrest. We should keep this in mind when interpreting the results of our study. Second, in-hospital mortality, the primary outcome of our study, can be influenced by many factors other than severity of trauma, such as treatment decision (e.g. withdrawal of the treatment). Therefore, we evaluated the association between the qSOFA score and requirement of transfusion using sensitivity analysis and confirmed similar results. Third, we evaluated consciousness using two different scales, the GCS and the JCS, which hampered the validity of our results. As consciousness is commonly evaluated by the JCS in the prehospital setting and the GCS in the hospital setting in Japan, our result might be applicable only to Japanese clinical settings. Thus, the generalizability of our results outside Japan is not guaranteed. Similarly, the vital signs were evaluated by different observers, mostly by emergency medical services personnel in prehospital settings and by physicians or nurses in hospital settings. For example, substantial interobserver difference in respiratory rate measurements was reported by a recent study, which could influence the results of our study.[13] Future studies are required to validate our results. Finally, consciousness, which is one of the three variables in the qSOFA score, could be affected by various factors, such as alcohol, addiction, and mental illness, other than brain injury. This can influence the result of our study, and we should cautiously interpret the predictive ability of the qSOFA score.

CONCLUSIONS

REPEATED CALCULATIONS OF qSOFA score improved its predictive accuracy for in-hospital mortality in trauma patients. Specifically, we should consider an increasing qSOFA score as a “red flag” to prompt clinicians to further evaluate patients and implement more aggressive

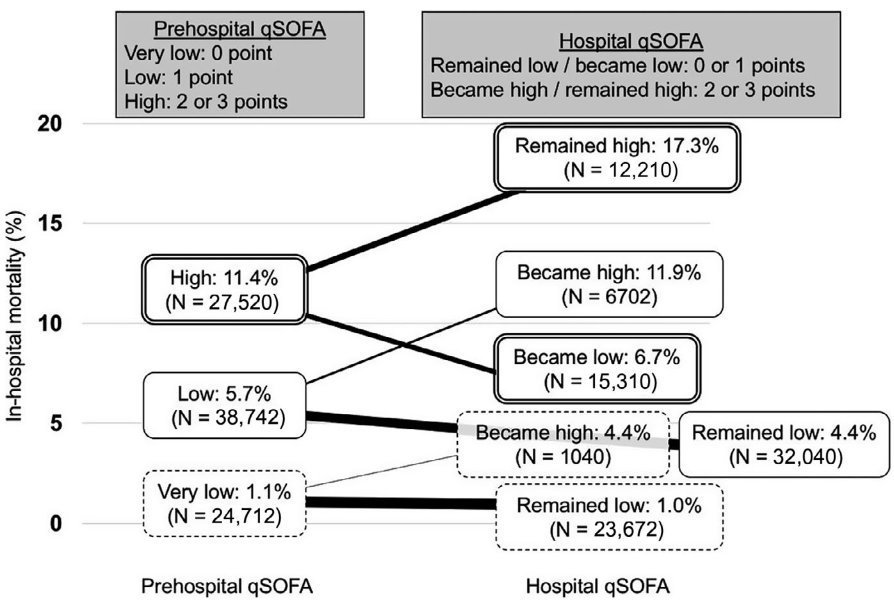

Fig. 4. Crude in-hospital mortality rate among Japanese trauma patients for each trajectory group of the quick Sequential Organ Failure Assessment (qSOFA) score.

Table 3. Odds ratio (OR) of quick Sequential Organ Failure Assessment (qSOFA) trajectory from prehospital qSOFA to hospital qSOFA in Japanese trauma patients, with respect to in-hospital mortality

Prehospital qSOFA	Hospital qSOFA	Crude OR	Partially adjusted OR	Fully adjusted OR
0	Remained low (0 or 1)	1.00	1.00	1.00
	Became high (2 or 3)	4.84 (3.47–6.63)	4.60 (3.27–6.32)	3.46 (2.41–4.85)
	Number of patients	24,712	24,712	23,877
1	Remained low (0 or 1)	1.00	1.00	1.00
	Became high (2 or 3)	2.97 (2.71–3.25)	3.04 (2.77–3.34)	1.86 (1.67–2.07)
	Number of patients	38,742	38,742	36,959
2 or 3	Became low (0 or 1)	1.00	1.00	1.00
	Remained high (2 or 3)	2.92 (2.70–3.16)	3.00 (2.77–3.26)	2.02 (1.84–2.21)
	Number of patients	27,520	27,520	26,007

Data are shown with 95% confidence intervals. In the partial adjustment model, we used age and sex as adjusters. In the full adjustment model, we used age, sex, mechanism of injury, cause of injury, and injury severity score as adjusters.

Table 4. Odds ratio (OR) of quick Sequential Organ Failure Assessment (qSOFA) trajectory from prehospital qSOFA to hospital qSOFA in Japanese trauma patients, with respect to requirement of transfusion within 24 h

Prehospital qSOFA	Hospital qSOFA	Crude OR	Partially adjusted OR	Fully adjusted OR
0	Remained low (0 or 1)	1.00	1.00	1.00
	Became high (2 or 3)	3.65 (3.03–4.37)	3.63 (3.01–4.34)	2.66 (2.18–3.23)
	Number of patients	24,712	24,712	23,877
1	Remained low (0 or 1)	1.00	1.00	1.00
	Became high (2 or 3)	2.94 (2.73–3.16)	2.95 (2.74–3.17)	1.91 (1.76–2.07)
	Number of patients	38,742	38,742	36,959
2 or 3	Became low (0 or 1)	1.00	1.00	1.00
	Remained high (2 or 3)	3.09 (2.91–3.27)	3.07 (2.89–3.26)	2.04 (1.91–2.18)
	Number of patients	27,520	27,520	26,007

Data are shown with 95% confidence intervals. In the partial adjustment model, we used age and sex as adjusters. In the full adjustment model, we used age, sex, mechanism of injury, cause of injury, and injury severity score as adjusters.

interventions for patients in the emergency department, when required.

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DISCLOSURE

Approval of the research protocol: The protocol for this research project was approved by a suitably constituted Ethics Committee of the institution and it conforms to the provisions of the Declaration of Helsinki. Committee of Wakayama Medical University, approval number 2632.

Informed consent: Informed consent was waived because of the retrospective nature of the study.

Registry and registration no. of the trial: UMIN-CTR, UMIN000037249 (registered 3 July 2019, https://upload.umin.ac.jp/cgi-open-bin/ctr/ctr_view.cgi?recptno=R000042402).

Animal studies: N/A.

Conflict of interest: Dr. Miyamoto reports the receipt of lecture fees from Becton Dickinson, Maruishi Pharmaceutical, and Radiometer.

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